

NOISE CHARACTERISTICS OF A JET AUGMENTED
FLAP CONFIGURATION

Alain Burraud

(NASA-TT-F-14951) NOISE CHARACTERISTICS
OF A JET AUGMENTED FLAP CONFIGURATION
(Linguistic Systems, Inc., Cambridge,
Mass.) CSCL 23A

N73-26030

Unclas
G3/02 08680

Translation of: " Caractéristiques acoustiques
d'un dispositif hypersustentateur à volet de
courbure soufflé", L'Aéronautique et l'Astro-
nautique, no. 39, 1973-1, pp. 44-54.



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546 JUNE 1973



1. Report No. NASA TT F-14,951	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle NOISE CHARACTERISTICS OF A JET AUGMENTED FLAP CONFIGURATION		5. Report Date JUNE 1973	
		6. Performing Organization Code	
7. Author(s) Alain Burrand		8. Performing Organization Report No.	
		10. Work Unit No.	
9. Performing Organization Name and Address LINGUISTIC SYSTEMS, INC. 116 AUSTIN STREET CAMBRIDGE, MASSACHUSETTS 02139		11. Contract or Grant No. NASW-2482	
		13. Type of Report & Period Covered TRANSLATION	
12. Sponsoring Agency Name and Address NATIONAL AERONAUTICS AND SPACE ADMINISTRATION WASHINGTON, D.C. 20546		14. Sponsoring Agency Code	
15. Supplementary Notes Translation of: "Caractéristiques acoustiques d'un dispositif hypersustentateur à volet de courbure soufflé", L'Aéronautique et l'Astronautique, no. 39, 1973-1, pp. 44-54.			
16. Abstract The STOL-type aircraft lift augmenting requires the use of very efficient devices which, however, are likely to be sources of noise themselves or may modify the noise generated by the jet-engines. Among these devices is the internal-flow jet augmented flap wherein a jet from auxiliary generators is directed onto the wing flap upper-surface. The noise of this device is to be added to that produced by the engines. Static tests recently performed in the CEPR anechoic chamber at Saclay have made it possible to investigate the various possible configurations and to appraise the effect of numerous parameters. The application of results at full scale allows the noise level of this STOL type to be evaluated.			
17. Key Words (Selected by Author(s))		18. Distribution Statement UNCLASSIFIED - UNLIMITED	
19. Security Classif. (of this report) UNCLASSIFIED	20. Security Classif. (of this page) UNCLASSIFIED	21. No. of Pages 20	22. Price \$600

NOISE CHARACTERISTICS OF A JET AUGMENTED FLAP CONFIGURATION†

Alain Burraud

The STOL-type aircraft lift requires the use of special systems to modify the acoustic fields and spectra emitted by the engines themselves. /45*

The noise characteristics of two types of such a system have been studied at the Aerospatiale supported by government agencies:

- the jet of air from the engines blows directly onto the wing-flap high-lift devices;
- the jets from the auxiliary generators or from the engine blows indirectly onto the upper surfaces of the wing flaps.

The second procedure consists of blowing through a slot on the trailing edge of the wing's fixed part onto a cambered wing flap. The wing's lift consequently increases:

- by "re-sticking" the boundary layer,
- by increasing circulation around the wing.

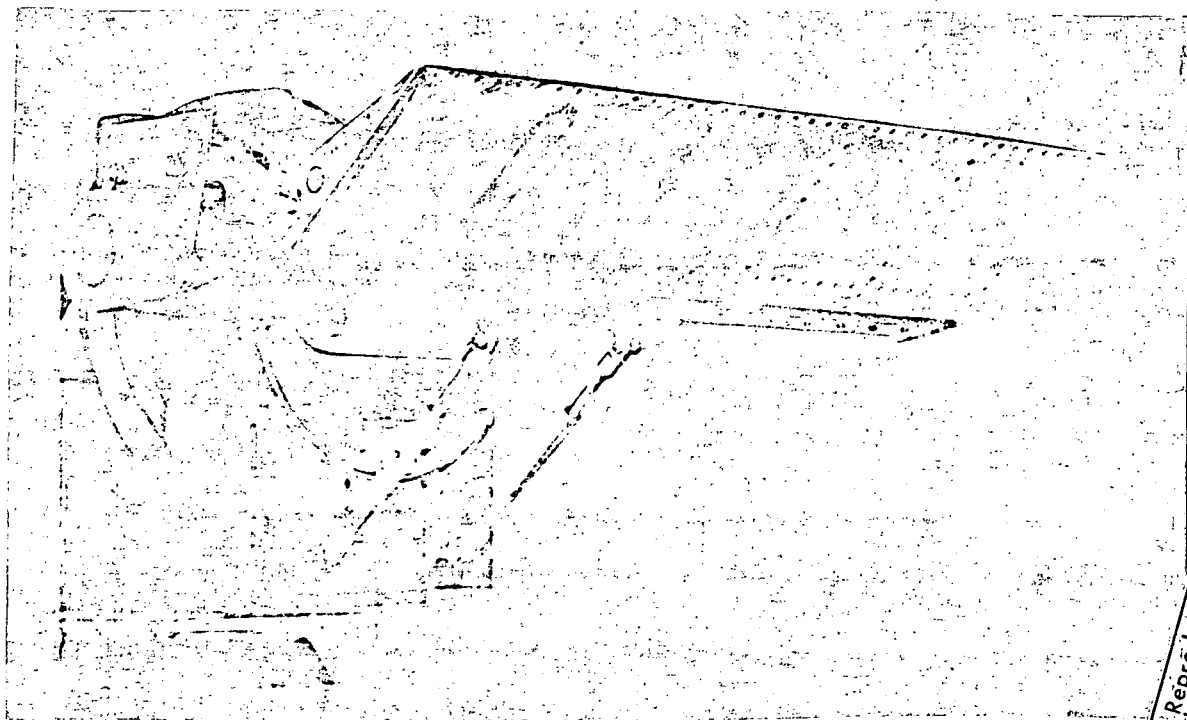
In the initial phase it was decided to study the noise characteristics of such a system at the fixed point only: tests could then be run under optimum conditions in the CEPr anechoic chamber at Saclay.

DEFINITION OF TESTS

Description of Model

The model features a classic blower directed onto a simple unslotted cambered flap (Figure 1).

*Numbers in right-hand margin indicate pagination in foreign text.
†Communication presented at the III Colloquium on Aeronautic Acoustics organized by AFITAE and GALF, Toulouse, March 6 and 7, 1972.



Reproduced from
best available copy.

Figure 1. Internal jet model

Since these noise tests were on the fixed point and there was no wing velocity, the entire fixed part of the airfoil did not have to be represented in the model and only the rear area was included, ending with a semicircle at the front.

The tight joint between the wing and the flap is very important from the aerodynamic point of view: it prevents flow from passing which would be likely to separate the boundary layer on the flap and thus damage the aerodynamic qualities of the system.

Since the sound field did not revolve and the microphone pick-up scanned in the horizontal fixed plane of the chamber it was necessary to scan successively for several lateral attitudes in each configuration: three of the model's lateral attitudes were systematically examined:

$\phi = 180^\circ$: measured in the plane of the wing; for experimental safety reasons the flaps were pointed towards the top of the anechoic chamber.

$\phi = 90^\circ$: measured in the flyover plane: a half-plane containing the lower surface of the wing below its aerodynamic chord. The model is mounted vertically, and the jets are deflected towards the center of the chamber.

$\phi = 135^\circ$: intermediate deflection.

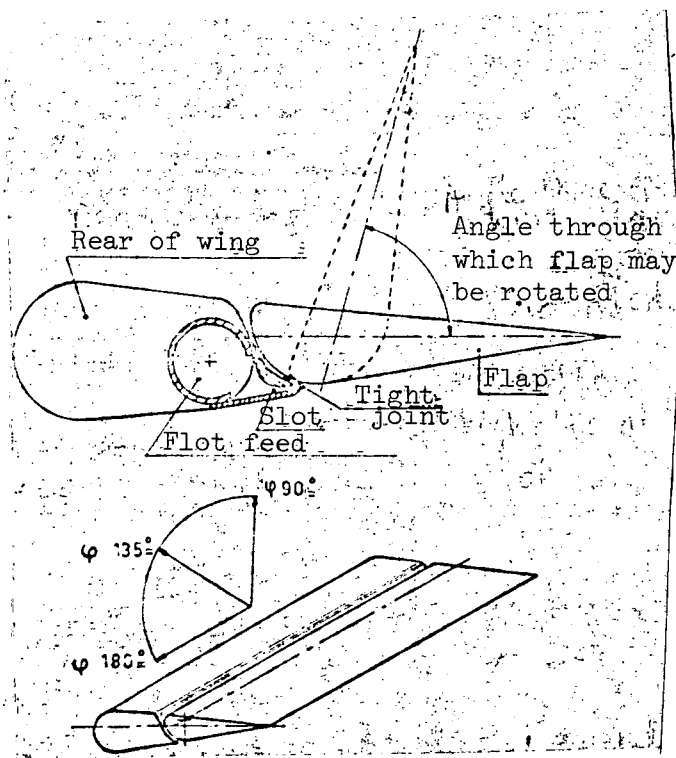


Figure 2. Test Model

The maximum span of the blown flap is 1 m and its chord is 0.25 m; for anticipated STOL aircraft designs such a flap chord would be on a scale between 1/8 and 1/4, the former for the wingtip chord and the latter for that of the wing socket.

The geometric variable parameters of the model are:

- h : height of ejection slot between 0.5 and 2 mm, giving a slot height/flap chord ratio of between 2/1000 and 8/1000. On an actual aircraft, this ratio might be between 1/1000 and 2/1000.

- d : Height of leading edge upper surface with respect to the slot.

- l : Length of slot: it is possible to blow either through the entire slot (1 m) or half of it (0.5 m).

- α H : Angle at which the curved flap is pointed: between 0 and 70°.

In the Saclay CEPr anechoic chamber the model is attached to the air intake tube by connecting components with minimum noise perturbation.

The expansion ratio is between 1.4 and 3, and the generating temperatures between 400 and 600°K; the exhaust speed range is 260 m/s to 480 m/s.

Noise Measurements

Noise measurements made at the CEPr, Saclay facility permit us to achieve:

- acoustic fields in dB around the model for azimuths between 15° and 160°.
- spectral analysis in thirds of a signal octave for points every 10°, azimuth-wise.

The noise measurements are corrected for the effects of atmospheric absorption. The total noise levels are calculated from the corrected spectra.

NOISE CHARACTERISTICS OF THE RECTANGULAR SLOT, WITHOUT THE FLAP

Bearing in mind the large number of parameters, the tests were run around a so-called "pivot" configuration characterized by the following parameter values:

$T_i = 400^\circ\text{K}$ $P_j/P_a = 1.76$ $h = 1 \text{ mm}$, and $l = 1 \text{ m}$
so that the length of the rectangular slot is 1000.

Influence of Expansion Ratio

In the flyover plant $\phi = 90^\circ$ we can observe that the acoustic fields are similar in form when the expansion ratio varies between 1.43 and 2.97 (Figure 3). The maximum total noise appears with azimuth between 40° and 50°. The fairly rapid drop in noise level

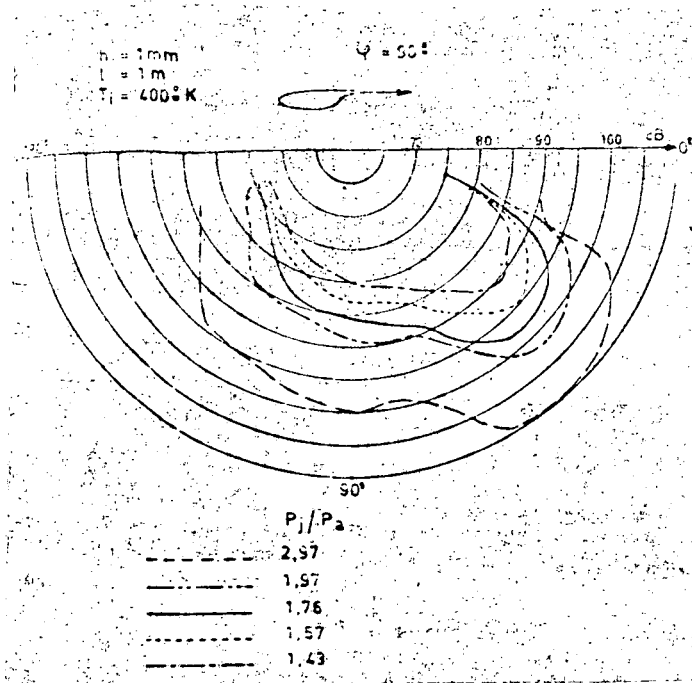


Figure 3. Influence of expansion ratios (acoustic fields, slot without flap)

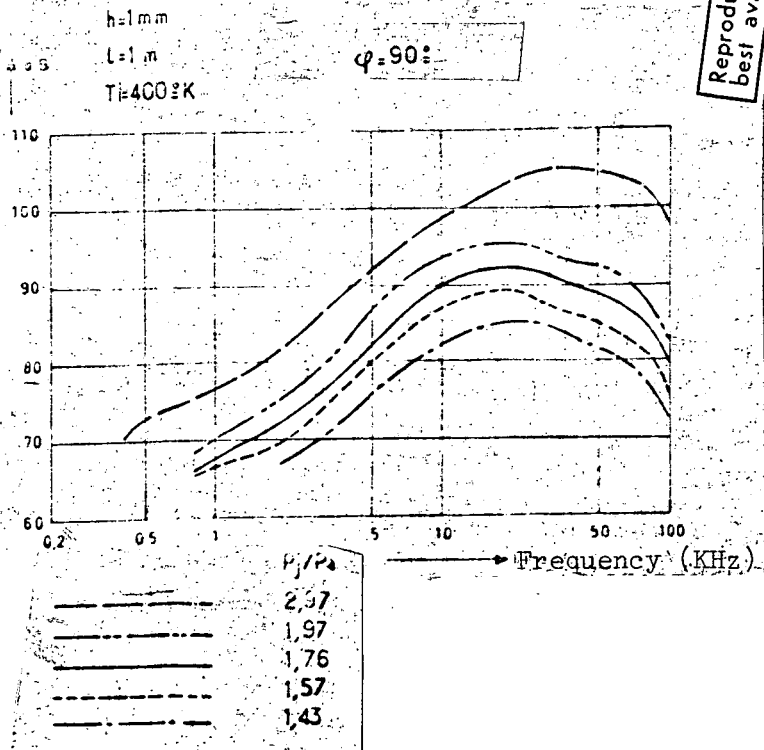


Figure 4. Influence of expansion ratios (spectra of maximum total noise, slot without flap)

starting from azimuth 135° derives from the masking /47 effect of the rear part of the model. Spectra for the maximum noise levels for each expansion ratio studied show maximum sound for frequencies between 20,000 Hz and 30,000 Hz, this frequency rising with a rising expansion ratio (Figure 4).

In the intermediate plane $\phi = 135^\circ$, the maximum total noise angle is between 50° and 60° , and the maximum total noise spectra are similar to those obtained in the flyover plane.

In the wing plane $\phi = 180^\circ$, a very sharp lobe of maximum sound emission does not appear: only very slight noise level increases at azimuths 30° and $90-100^\circ$ (Figure 5).

The spectra for the /48 maximum total noises are very flat and the maximum noise frequency always moves up to higher frequencies when the expansion ratio increases (Figure 6).

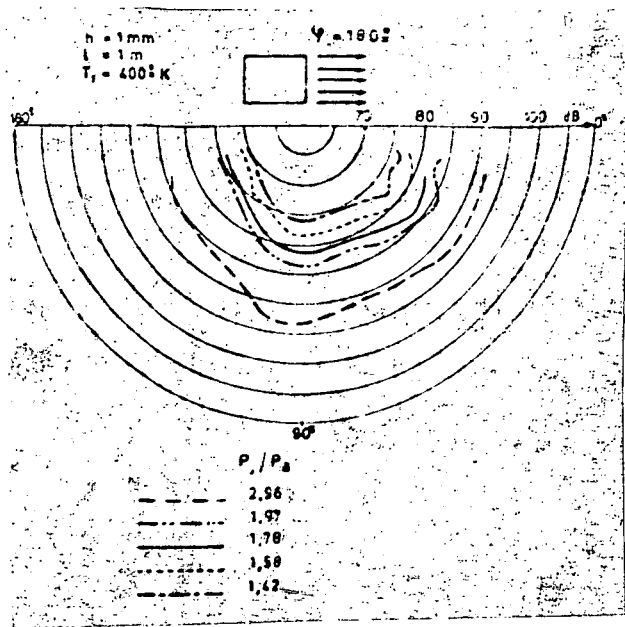


Figure 5. Influence of expansion ratio (acoustic fields, slot without flap)

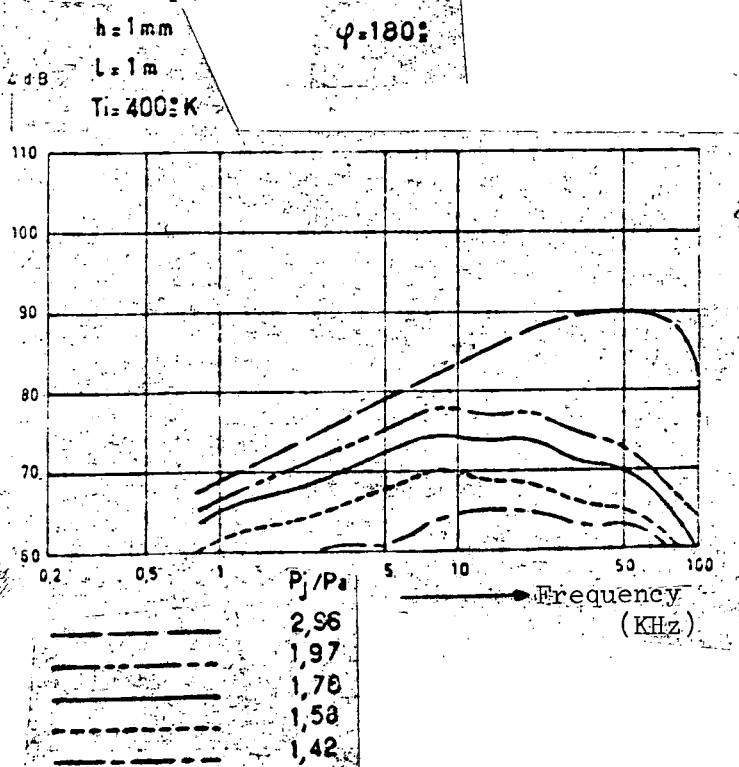


Figure 6. Influence of expansion ratio (maximum total noise spectra, slot without flap)

Variation of Maximum Total Noise Level Plotted against Jet Exhaust Speed

Figure 7 shows, for the three lateral attitude studied, the pattern of maximum total noise as a function of exhaust speed. When the expansion ratio is supersonic, the speed was calculated by assuming total expansion.

At subsonic speeds it is found experimentally that noise intensity corresponding to maximum total noise follows different velocity laws according to the plane of measurement, $V^{8.5}$ for flyover plane $\phi=90^\circ$, $V^{6.9}$ in the intermediate plane $\phi = 135^\circ$, and $V^{5.8}$ in the wing plane $\phi = 180^\circ$. On the other hand, for supersonic speeds, the experimental laws derived are substantially the same: $V^{9.5 \pm 0.2}$.

Thus, we find for the very long rectangular slot the same result known for the circular nozzle, i.e.

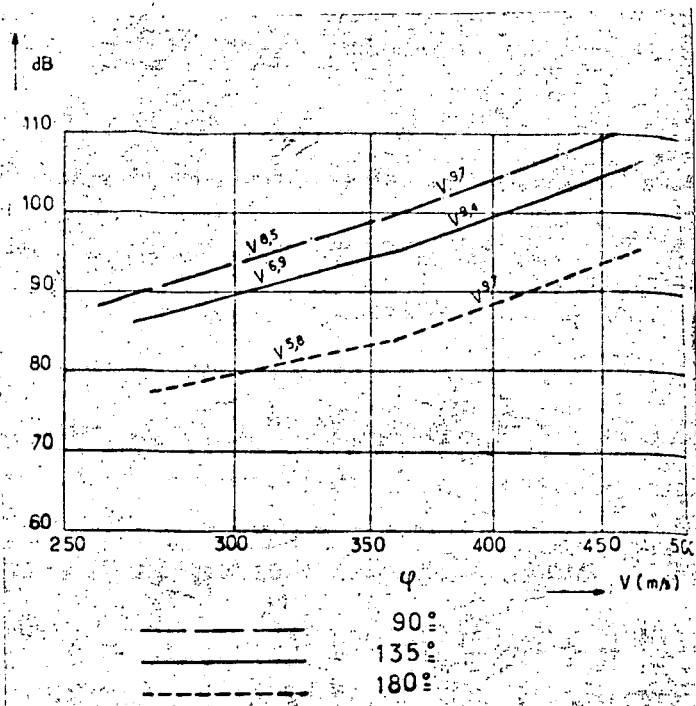


Figure 7. Maximum total noise level plotted against jet speed. (slot without flap)

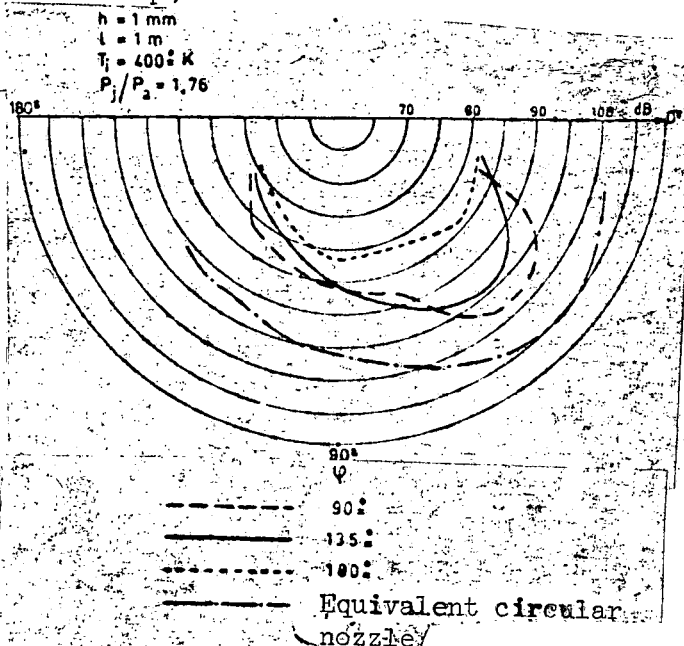


Figure 8. Influence of lateral attitude (acoustic fields, slot without flap)

greater rise in noise intensity as a function of speed for supersonic than for subsonic speeds.

Influence of Generating Temperature

When, at expansion ratios constant and equal to 1.76, the temperature rises from 400°K to 600°K, the noise levels increase but less than the velocity laws indicate, which is normal because, correlatively, the density of the jet diminishes.

In the flyover plane this temperature increase of 200°K causes a noise level increase of about 4 dB.

Influence of Lateral Attitude

Comparison with a Circular Nozzle with the Same Outlet Section

If we compare the acoustic fields obtained for the three different lateral attitudes and for the same generating conditions, we find a large decrease in the sound levels when passing

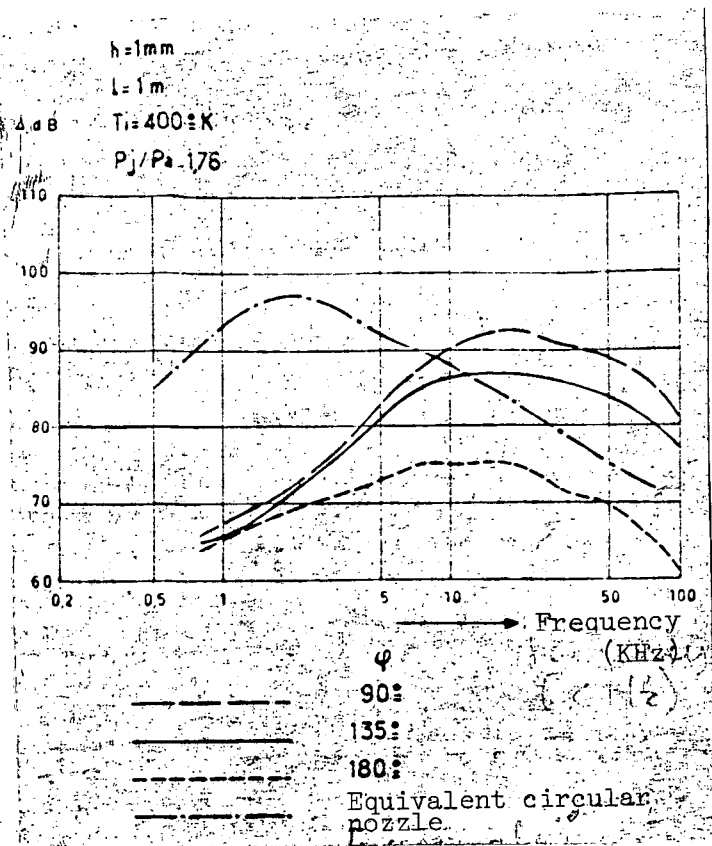


Figure 9. Influence of lateral altitude (noise spectra)

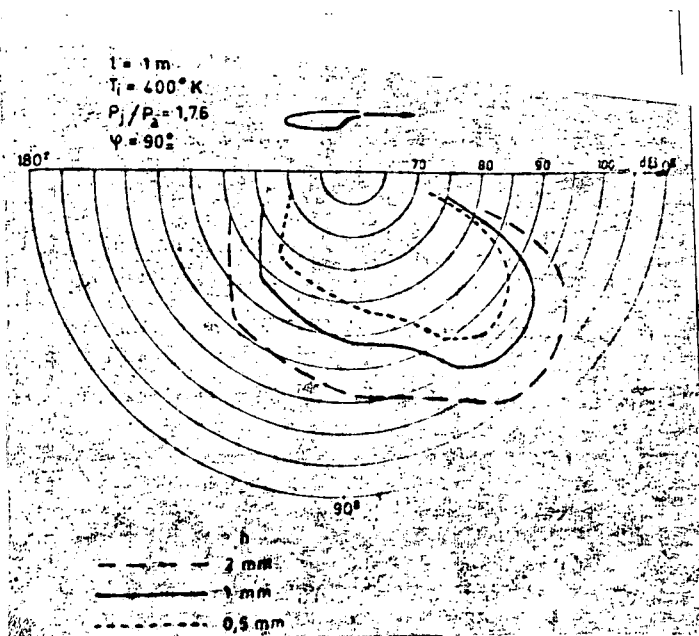


Figure 10. Influence of slot height (acoustic fields, slot without flap)

from the flyover plane to the wing plane, which decrease reaches 15 dB in the downstream azimuths (Figure 8). This figure also plots the acoustic field obtained with a converging circular nozzle with the same outlet section as the rectangular slot and functioning under the same generating conditions. We find that the sound level of the rectangular slot is far less than that of the converging nozzle with the same outlet section; in fact if the sections are equal the perimeters are very different since they are 2 m for the rectangular nozzle and only 11 cm for the circular nozzle: the mixture with the ambient air is thus favored by the rectangular nozzle and hence the noise energy emitted is smaller.

Comparison of the spectra for the maximum total noises shows a shift towards the high frequencies when going from the circular nozzle to the very long rectangular slot; the center frequency rises

from 2000 Hz to 20,000 Hz. The rectangular slot thus shows a decrease/49 in noise energy in the low frequencies and increase in noise energy in the high frequencies: this is positive for the noise level drop since the high frequencies attenuate much faster as a function of distance than the low frequencies (Figure 9).

Influence of Slot Width

With a given slot height, the emitted noise level difference in the flyover plane between a slot 1 m wide and that 0.5 m wide is 3 dB.

It should thus be possible to extrapolate results from very long models to full scale, for a given slot height, if we consider that the increase in noise levels going from width l_1 to width l_2 is equal to

$$10 \log \frac{l_2}{l_1} \quad (\text{classic flow law})$$

Influence of Slot Height

To facilitate transposition of model results to a full-scale aircraft, measurements were made under the same generating conditions for slot heights 0.5 mm, 1 mm, and 2 mm (width 1 m). The differences obtained cannot be explained merely by the differences in flow since these produce more than 3 dB, whether we are going from $h = 0.5$ mm to $h = 1$ mm or $h = 1$ mm to $h = 2$ mm (Figure 10).

In addition, the flow coefficients ($C_F = \frac{\text{real flow}}{\text{theoretical flow}}$) were measured for different slots and proved to be very close to each other; moreover the slot is very rigid and the cross-section does not change when the pressurized jet passes through the model.

One possible explanation derives from the fact that the sound /50 energy in slots of this type is concentrated in the high frequencies, all the more so when the slot height is small. Now, for these high

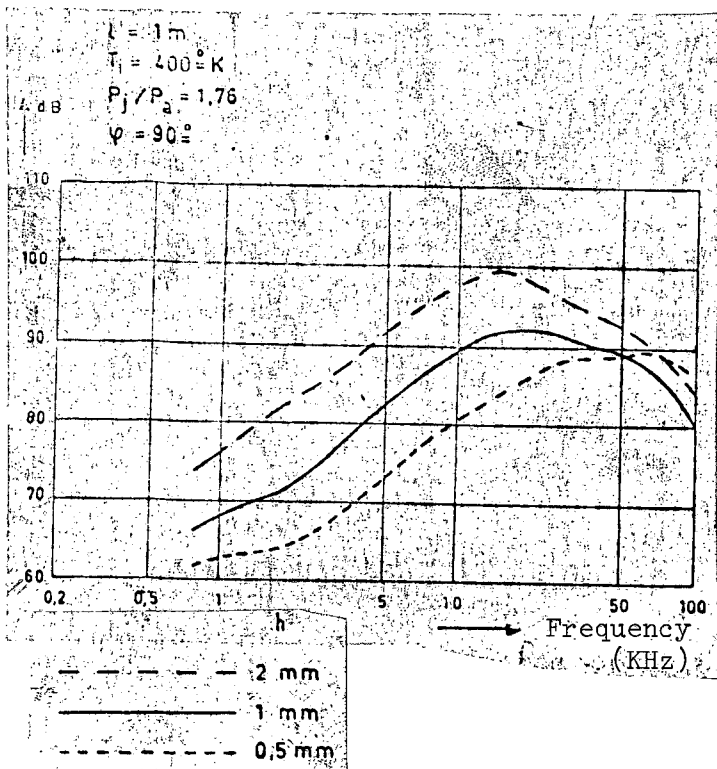


Figure 11. Influence of slot height (maximum total noise spectra, slot without flap)

frequencies atmospheric absorption is very large, on the order of a dB per meter (measurements were made at 6 meters) and increases rapidly with frequency (Figure 11).

Some measurements were made to compare the sound levels of rectangular slots with different heights and converging nozzles with the same outlet section as the rectangular slots (Figure 12). We see from this figure that the difference between the maximum total levels increases with decreasing slot height h .

NOISE CHARACTERISTICS OF THE RECTANGULAR SLOT WITH FLAP

Influence of the Presence of the Flap and its Pointing Direction, Flyover Plane
 $\psi = 90^\circ$

Compared to the noise level of the slot without a flap, the presence of the straight flap causes a very large drop in sound levels by a masking effect, reaching 17 dB in the direction of maximum noise for

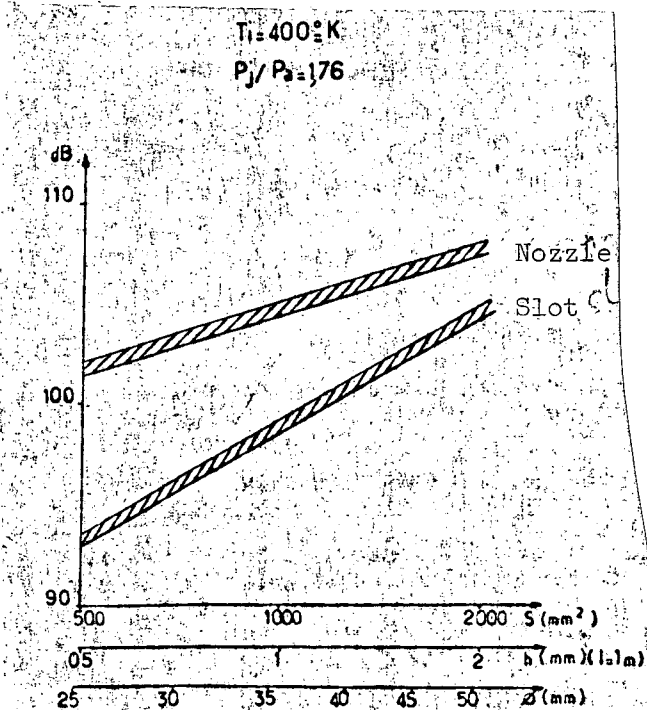


Figure 12. Maximum total sound levels (comparison between rectangular slots and circular nozzles with the same cross-section)

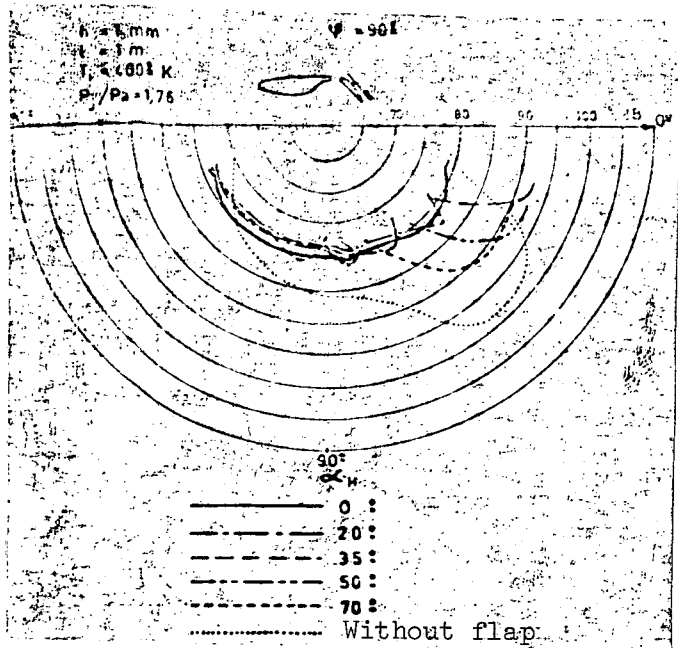


Figure 13. Influence of flap direction (acoustic fields, slot with flap)

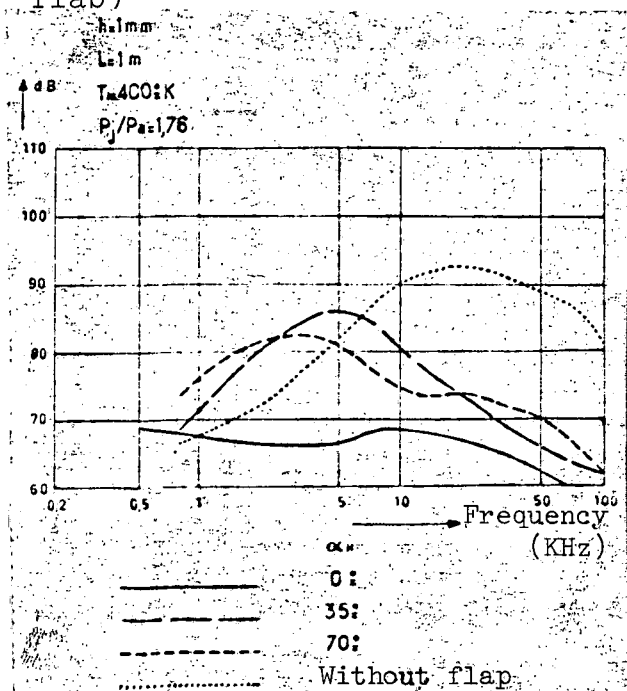


Figure 14. Effect of flap angle (maximum total noise spectra, slot with flap)

the generating conditions considered ($p_j/p_a = 1.76$ $T_i = 400^\circ\text{K}$). This drop is due to the very favorable effect of the flap height/flap chord length ratio, which is 4:1000. At takeoff, therefore, it would be advantageous to bring in the flaps as soon as possible as far as safety permits to benefit from the /51 masking effect, even without stopping the jet from blowing on them (Figure 13).

This beneficial effect would obviously not be noticed by observers "seeing" the top of the wing.

When the flap is at a 35° angle, for example, the jet, following the upper flap surface, is directed groundward: then the noise levels rise in the zone of the azimuths which no longer benefit from the masking effect and, in the masked part, we find the noise levels obtained with the straight flap. When the flap angle increases, and the jet continues to adhere

to the upper surface, the downstream noise zone extends at the same angle as the flap. We can also see that the maximum noise levels found in the non-masked part are less than the maximum noise level of the slot without a flap. It is possible also to note that the flap angle itself has no influence of the noise levels, but only on the size of the noise zone.

The acoustic fields are interrupted at azimuths where the microphone pickup is in the jet and where, hence, noise measurement is no longer valid. Anemometric measurements have shown that the blast across the microphone pickup reached speeds of 10 m/s.

Comparison of the maximum total noise level spectra of the slot without flap and the flap at an angle shows that the spectrum slides towards the lower frequencies and the sound energy rises in the frequencies less than 500 Hz with a sharp drop of energy in the high frequencies: the drop throughout the frequency range over 15,000 Hz is about 20 dB. The favorable role of atmospheric absorption will thus be far less when the flap is at an angle and the sound energy will now be concentrated in the frequency zones which are very unpleasant for the observer (maximum discomfort) (Figure 14).

Intermediate Plane $\psi = 135^\circ$

/52

The results are similar to those obtained at $\psi = 90^\circ$:

- Favorable masking effect for the straight flap causing a noise level drop of 11 to 12 dB in the maximum noise direction.
- When the flap is at an angle the noise levels rise again for azimuths to the side of the jet, and this noise zone extends with a higher flap angle.

The presence of the flap slightly diminishes maximum noises (by 2 dB).

- The spectra slide down towards low frequencies.

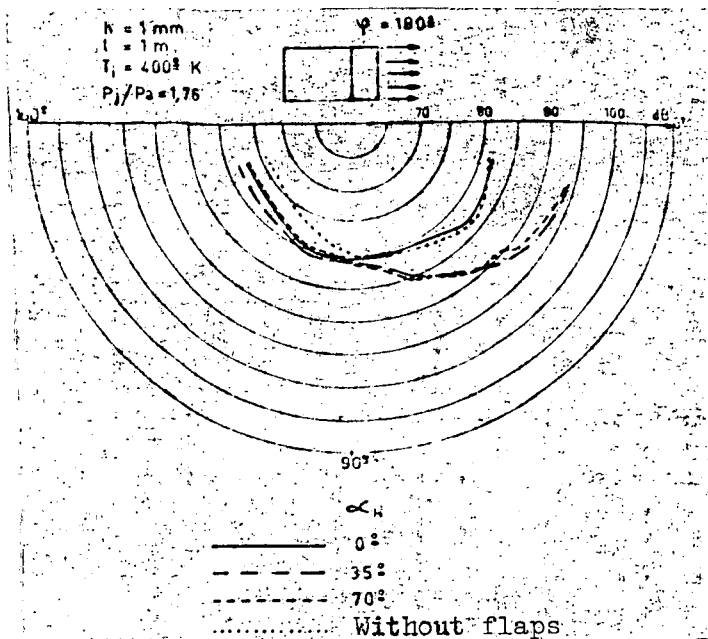


Figure 15. Influence of flap angle (acoustic fields, slot with flap)

Wing Plane $\psi = 180^\circ$

The presence of the straight flap causes no change in the sound field of the slot without flap. On the other hand, when the flap is at an angle, the jet in this case pointing downwards because of its directivity, a noise increase is produced in the lateral plane, which is on the order of 10 dB for small azimuths and disappears in the slot plane for θ greater than 90° (Figure 15).

Influence of Lateral Attitude

If we draw the acoustic fields for the three lateral attitudes studied for the slot with flap ($\alpha = 70^\circ$) we find a certain symmetry of revolution, which was not the case for the flap-less slot where there were large differences between the flyover plane and the lateral plane (Figure 16).

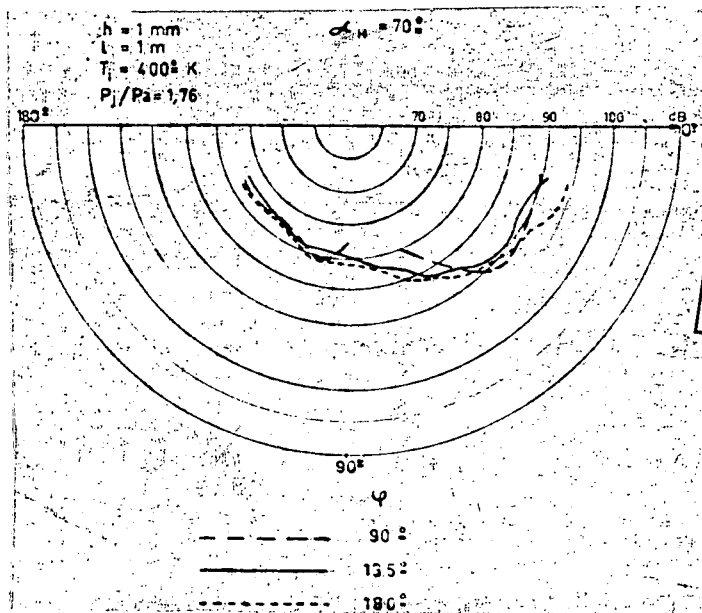
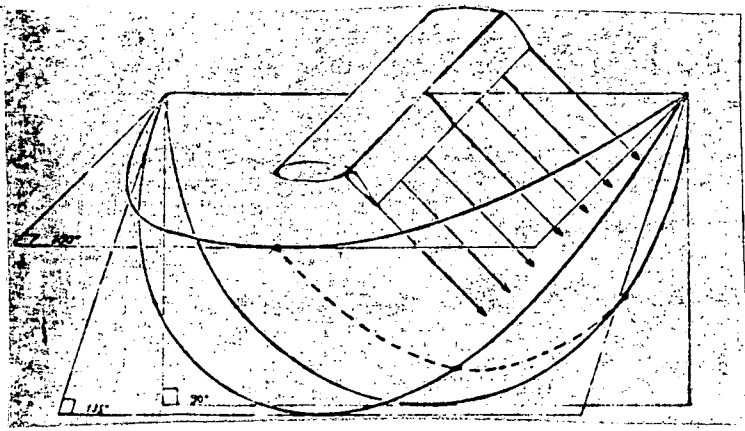


Figure 16. Influence of altitude (acoustic fields, slot with flap)

In fact, the presence of the flap does not create extra noise and would even



— Path scanned by microphone pickup
 — Plane scanned by microphone pickup
 — Plane of jet
 --- Limit of vision, flap lower/upper surface

Figure 17. Perspective view of measurement planes

tend to decrease it with $\psi = 90^\circ$, but, since the jet is directed towards the ground due to its directivity, the large attenuation found for the flap-less slot is lost in the lateral plane (Figure 17).

Influence of Expansion Ratio or of Jet Temperature

When the expansion ratio or the jet temperature is made to vary we find, for the slot with flap, the same modifications as in the noise characteristics of the flap-less slot.

Influence of Slot Height

The differences between the noise levels found for the flap-less slot when its height goes from $h = 1 \text{ mm}$ to $h = 2 \text{ mm}$ are of the same order of magnitude when the slot has a flap at an angle. For the flap-less slot, atmospheric absorption could explain these differences; the presence of the flap causes the spectra to slide down towards the lowest

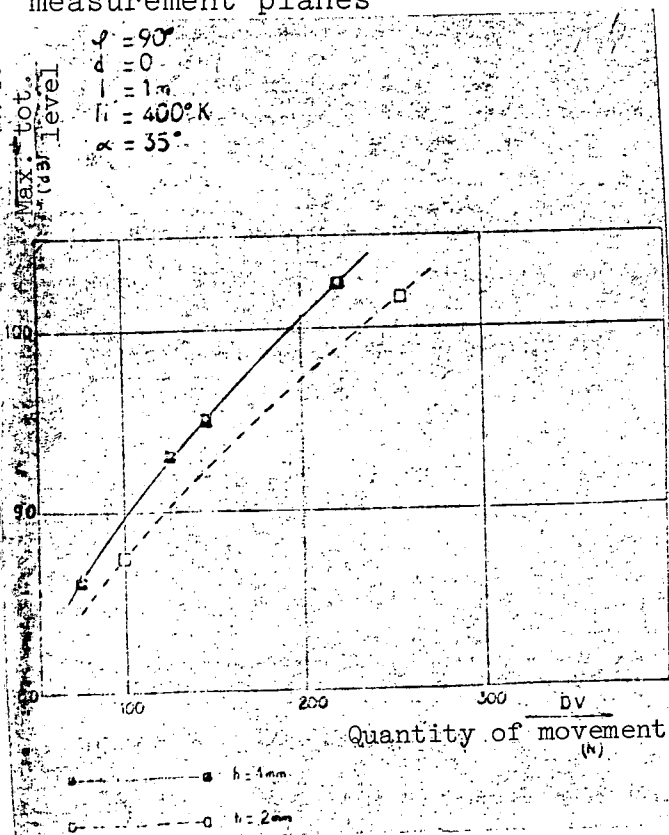


Figure 18. Total sound level plotted against amount of motion.

Reproduced from best available copy.

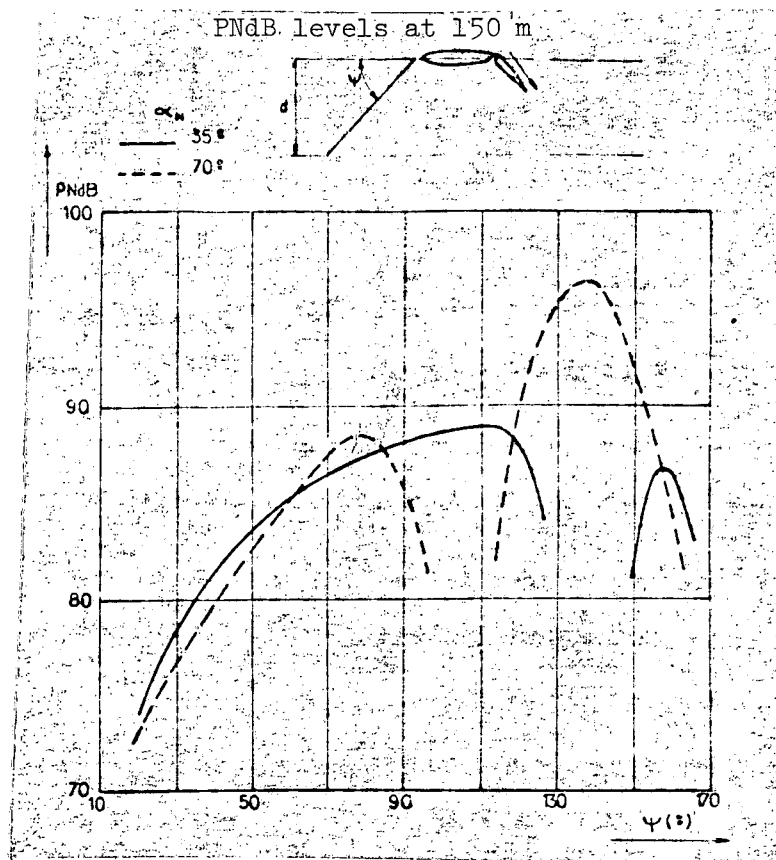


Figure 19. Preliminary STOL design, linear acoustic fields due to high lift by internal-flow jet

frequencies since the central frequency of these spectra is in the 3000-5000 Hz range, in which atmospheric absorption plays much less of a part. In the case of the slot with flap the differences found when the slot height increases (7 to 10 dB when height increases from 1 to 2 mm) can be connected with the correlative increase of the slot height/flap chord ratio where the masked zone is concerned, and to the ratio of slot height to flap radius of curvature ratio in the jet zone. This is an important point, especially for transposition to full scale, and requires additional testing.

Comparison of Noise Levels for Different Slot Heights with the Same Amount of Motion

From the aerodynamic viewpoint, what we must consider is the quantity of DV jet movement leaving the slot. Other things being equal, the noise level increase is large with a slot height increase from 1 to 2 mm. As a result, for a given quantity of movement, the noise level gain is small if we choose a 2 mm height slot with a small exhaust speed rather than a 1 mm height slot with a higher exhaust speed (Figure 18).

Influence of the Flap Leading Edge Upper Surface Height with Respect to the Jet Axis

Where the system's aerodynamic qualities are concerned, it is extremely detrimental for the jet not to leave the flap leading edge tangentially. On the other hand, the noise levels remain practically unchanged when the height of the flap leading edge upper surface increases with respect to the jet axis.

ESTIMATE OF INTERNAL JET NOISE OF A STOL AIRCRAFT

/54

Until further studies and tests are performed to specify the influence of certain characteristics (slot height, ratio between slot height and flap chord) on the internal jet noise levels, it seemed interesting, if only to obtain orders of magnitude, to transpose the results obtained from the model to an estimate of the internal jet noise levels for a full-scale STOL aircraft (Figure 19).

This evaluation was made for an Aerospatiale preliminary design. The transposition was made from results obtained for a 2 mm slot height, which height is the nearest to that of the average slot (4.5 mm) of the contemplated design. No account was taken, however, of the difference between the values of the slot height parameter flap chord concerning the model and the STOL design.

The linear sound fields calculated in PNdB for a distance of 150 meters are shown on Plate 26: for takeoff, the flap angle chosen is 35° and for approach, 70°. The values obtained lead us to believe that, at takeoff, the internal-flow jet noise would not predominate in the total aircraft noise unless, of course, substantial progress is made in the noise of the turbojets with which STOL aircraft may be equipped. At approach, however, when the engines are turning over slowly, the internal jet noise could be the chief component of the discomfort caused by internal-flow STOL aircraft.

CONCLUSIONS

Noise measurements on the internal-flow jet system carried out on a model at CEPr, Saclay, gave very interesting results on the sound fields and spectra of very long slots, with and without a cambered flap, for various generating conditions.

Systematic measurements taken for three lateral attitudes supplied the entire pattern of the acoustic field around the model.

The noise level differences found when modifications were made to the model's geometry, in particular slot height, require further study and testing before the full-scale transposition can be accurately made and the compromise between the system's aerodynamic and acoustic quantities can be better understood.

Also, the effect of the aircraft's forward motion on noise levels must be studied, as must the acoustic fields "on the wing", as STOL-type aircraft can have longitudinal attitudes important for takeoff.

Going by present hypothesis, transpositions to full scale show that the internal jet noise will certainly be the most important noise component at approach; however the values obtained do not permit us to rule out the internal-flow jet as a solution to the STOL problem.

REFERENCES

1. COLES W.D. - Jet-engine exhaust noise from slot nozzles.
Nasa TN D-60.
2. MAGLIERI D.J., HUBBARD H.H. - Preliminary measurements of the noise characteristics of some jet-augmented-flap configurations.
Nasa Memo 12-4-58-L.
3. DORSCH R.G., KREISA E.A., OLSEN W.A. - Blown flap noise research.
AIAA Paper n° 71.745.
4. GROSCHE F.R. - Noise generation by a turbulent jet over a flat surface of finite size. Max Plank Institut Nr 45.